62-116



# HIGH-FREQUENCY OSCILLATIONS IN A LOW-PRESSURE DISCHARGE

By

I. A. Savchenko and A. A. Zaytsev

FTD-TT- 62-116/1+2+4

# UNEDITED ROUGH DRAFT TRANSLATION

HIGH-FREQUENCY OSCILLATIONS IN A LOW-PRESSURE DISCHARGE

By I. A. Savchenko and A. A. Zaytsev

English Pages: 9

Source: Vestnik Moscovskogo Universiteta, No. 2, pp. 19-25, 1961.

SC-1053
SOV/188-61-0-2-4/10



PREPARED BY:

TRANSLATION SERVICES BRANCH
FOREIGN TECHNOLOGY DIVISION
WP-AFB, OHIO.



P

# HIGH-FREQUENCY OSCILLATIONS IN A LOW-PRESSURE DISCHARGE

I. A. Savchenko and A. A. Zaytsev

Electron plasma oscillations were investigated. The plasma was generated and controlled by an electron beam. The results of the investigation show that the character of the observable oscillations severely vary on the plasma boundaries.

## Introduction

High-frequency electron plasma oscillations have been studied by many authors [1-11]. Interest in the study of plasma oscillations was to a considerable extent evoked by the problem of abnormal electron scattering in plasma [3, 4]. Plasma oscillations are always present in a gas discharge, and knowledge of the mechanism of their origination can serve as a key to understanding many phenomena taking place in plasma.

It is now known that electron oscillations are also encountered in electronic instruments, creating excess interference in them. It is also suggested that the radio emissions of the sun and stars can be explained by plasma oscillations.

Experimental studies of electron plasma oscillations can be divided into two groups based on the method of investigation. In the first group are the studies [1-6] in which the plasma is generated and controlled by an electron beam. In the second group are the later studies [8-11] in which a monoenergetic beam of electrons was injected into an independently generated plasma.

Merrill and Webb [4] revealed that the distribution of scattering regions of the electron beam has a periodic character and these scattering regions are associated with the excitation regions of strong electron oscillations.

The results of Merrill and Webb's experiments were theoretically examined by Vlasov [12] and Bohm and Gross [13]. The authors propose that the totality of the phenomena detected by Merrill and Webb is explained by phase focusing of the electron beam producing a velocity modulation as the electrons pass through a fluctuating double layer at the plasma boundary.

However, these theories operate with a semi-bounded plasma and consider only the effects on the boundary of the injection of the beam into the plasma.

In the present work we experimentally investigated the effect of plasma boundaries on the excitation conditions and distribution of the strength of the electron oscillations of the plasma.

## Experimental Procedure

In the present work we studied oscillations in a low-pressure discharge with an incandescent cathode. We used a flat, indirectly heated oxide cathode with a diameter of 3 mm. The discharge vessel was a cylindrical tube 65 mm in diameter. The discharge burned in Ar at pressures of 4-10 $\mu$. The electrons emitted from the anode were accelerated by the cathode drop.

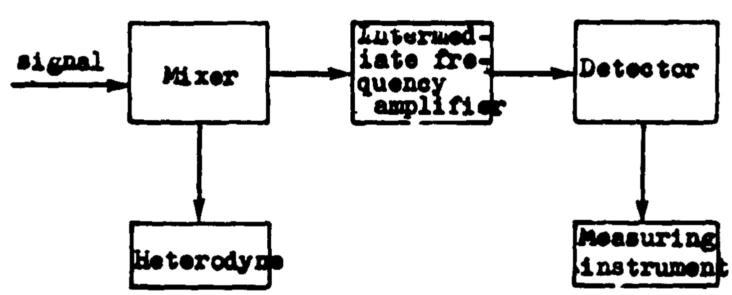



Fig. 1. Block diagram of measuring device.

In addition to the cathode, the discharge tube contained two more electrodes:

a movable electrode opposite the cathode and a side electrode. The movable electrode could be used as an anode or as an electron reflector. In the second case the discharge was ignited by feeding a voltage between the cathode and side electrode.

The indicator of oscillations was a cylindrical probe with a diameter of 0.08 mm with an unglazed part 3 mm long. The probe could be moved along the axis of the tube between the anode-cathode interspace or between that of the cathode-reflector; its position was noted within an accuracy to 0.2 mm. When the probe moved inside the beam we noticed an excitation of the beam by the probe, and the measurements were not free from distortions because of this (see [5]). Therefore, in our measurements the probe only touched the beam; this was achieved by turning the slide on which the cathode was mounted with a small assymetry. With this position of the probe its effect on the value and distribution of the oscillation intensity is almost eliminated.

Oscillations were detected by means of a superheterodyne circuit connected with the probe through the capacitor (Fig. 1). The intermediate frequency was 30 Mc, the amplifier pass band of the intermediate frequency was 10 Mc.

## Effect of Discharge Shape on Oscillations

The primary electrons ejecting from the cathode surface as a parallel beam, as a rule, undergo angular scattering 6-10 mm from the cathode. The following discharge shape can be observed depending on the pressure.

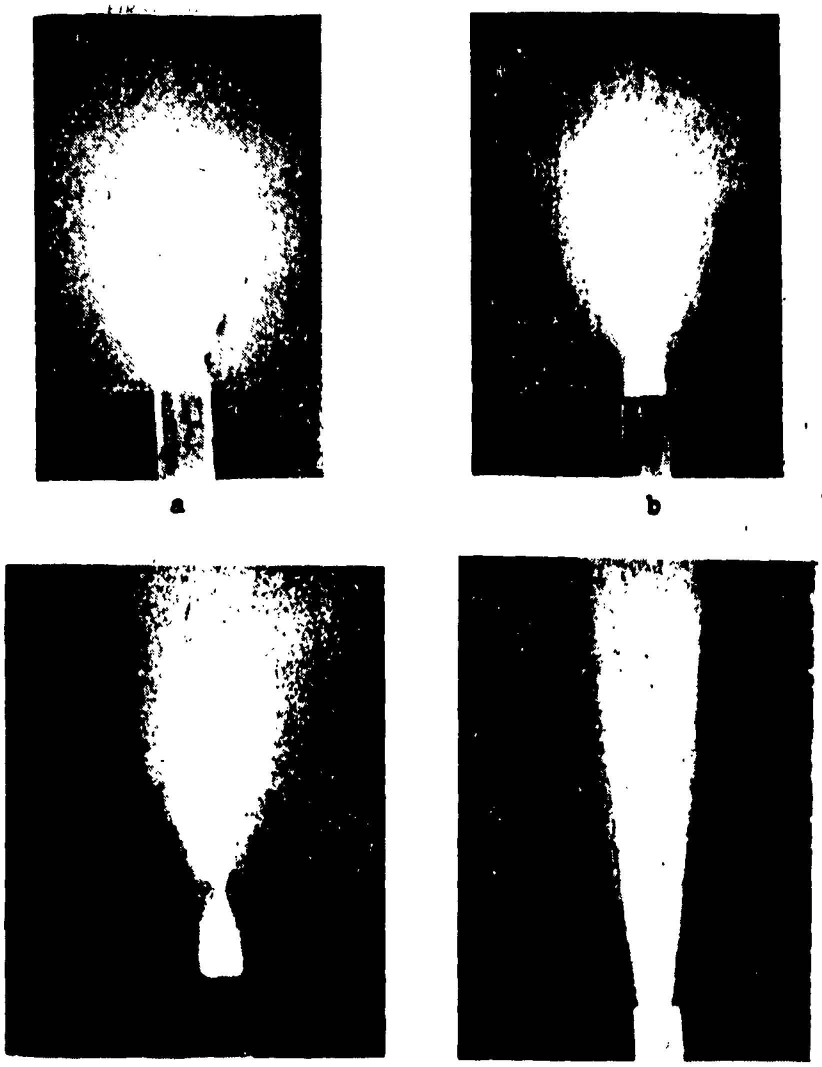
1. At gas pressures of the order of 10 $\mu$ and a discharge current of several tens of milliamperes, the parallel beam of electrons abruptly scattered (Fig. 2a). When the pressure drops a node is formed (Fig. 2b) which becomes all the more noticeable as the pressure continues to drop. We could observe only comparatively weak oscillations in these cases.

2. Convergence of the beam into a node continued at a pressure of 7 $\mu$.

Scattering arises after convergence; the intensity of the oscillations increased noticeably.

3. At a pressure of $5\mu$ a sharp node is formed about 6 mm from the cathode, scattering also occurs after the node forms. The oscillation intensity increases by about ten times in comparison with case 2 (Fig. 2c). Oscillations were accompanied by radiation.

4. A drop in pressure below $3\mu$ leads to the formation of a uniformly diverging beam (Fig. 2d). Oscillations were not detected with such a discharge shape.




c d

Fig. 2.



62-116/142

## Distribution of the Oscillation Intensity Along the Beam in the Case of a Discharge Between the Cathode and Movable Anode

The results of studying the distribution of the intensity of oscillations are shown in Fig. 3. The oscillation intensity is plotted along the ordinates, the distance of the probe from the cathode on the abscissa. The graphs of Fig. 3a, b, c were obtained for three different cathode-anode distances. We note that the distribution of oscillation intensity at anode cathode distances smaller than 26 mm has a sharply expressed periodic character. The distance between the maxima of the curves is about 3.5 mm. At larger distances d the curve monotonically increases and passes through the maximum in the plasma region at a distance of 20 mm from the cathode.

It is necessary to note that in the case of small anode-cathode distances, stronger oscillations are observed. The maximum on the curve of Fig. 3c is at a smaller distance from the cathode than the gas-kinetic mean free path for electrons (in this case $\lambda \simeq 5$ cm).

The formation of a periodic distribution at small anode-cathode distances is the consequence of the effect of the plasma boundaries. We can assume that the electrons reflected from the anode surface generate a feedback, thanks to which the formation of a standing wave and an amplification of the oscillations become possible.

To check this assumption, a grid having a separate lead-out was placed in one of the tubes 2 mm in front of the anode. Curve a in Fig. 4 corresponds to the case where the grid is connected with the anode. Feed of a negative potential relative to the anode (— 30 v) to the grid dampens the oscillations and simultaneously smooths out the curve (curve b).

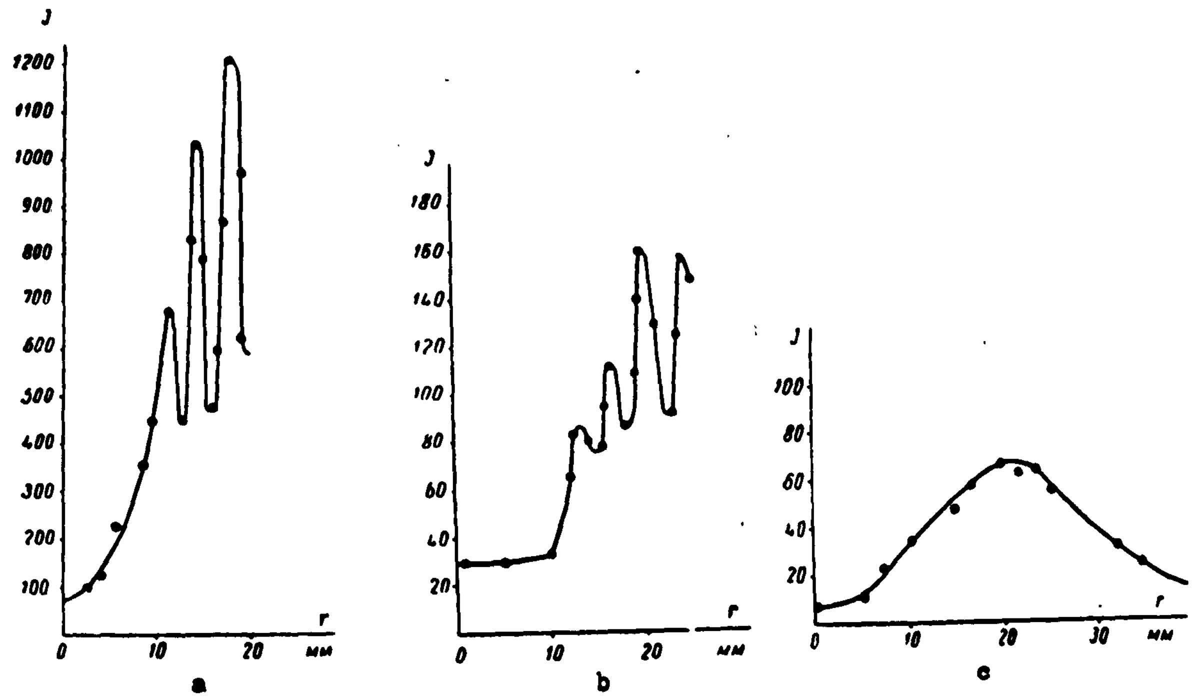



Fig. 3. Distribution of the oscillations intensity along the beam at different distances (d) from the cathode to the anode. Pressure 5 $\mu$, current 61 ma, voltage of the discharge burning 44 v, oscillation frequency 1050 Mc:

a) d = 19 mm; b) d = 26 mm; c) d = 40 mm.

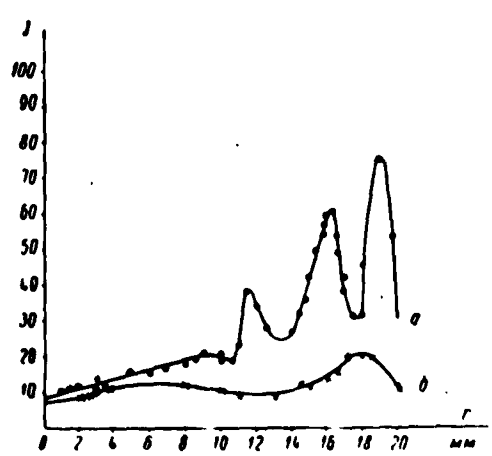



Fig. 4. Few electrons of the primary beam impinge on an anode located at a great distance from the cathode, and the number of reflected electrons is insufficient to generate an efficient feedback. This can explain the smooth shape of the curve of the distribution of oscillation intensity shown in Fig. 3c.

## Effect of a Reflector on the Character of Distribution of the Oscillation Intensity

When the movable electrode is under a negative potential relative to the cathode, the electrons are repulsed backward into the plasma by the braking field created near the reflector. Consequently, feedback can be realized by reflected electrons. Actually, the curves of Fig. 5 clearly show the periodicity in the distribution of the intensity of oscillations when the reflector is 27 mm from the cathode. These curves were obtained at different values of the negative potential of the reflector relative to the cathode (the same magnitudes are laid out along the coordinates as in Fig. 3). As the distance of the reflector from the cathode increases, its effect on the character of oscillations gradually decreases and in the end disappears.

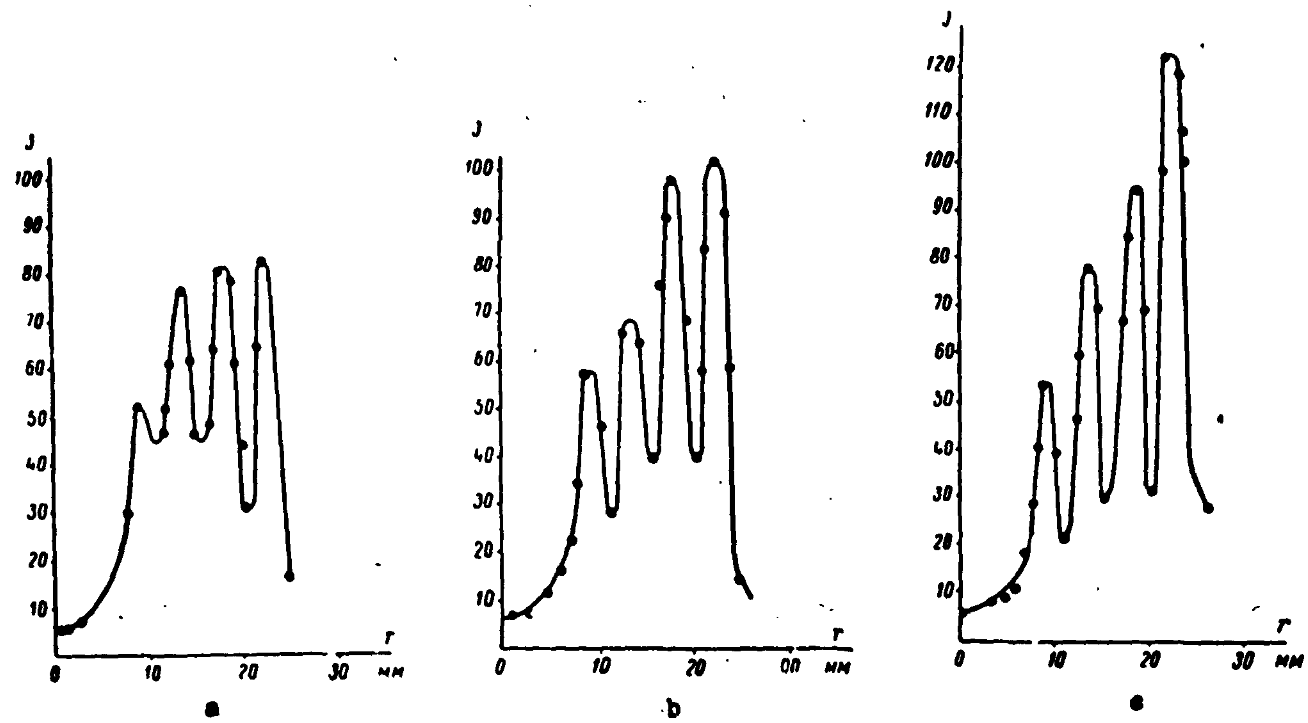



Fig. 5. Effect of reflector potential on the picture of the distribution of the oscillation intensity. Pressure 5 $\mu$, current 58 ma, voltage of discharge burning 58 v, oscillation frequency 1050 Mc:

a) floating reflector; b) reflector potential, 30 v relative to the cathode; c) reflector potential, 15 v relative to the cathode.

## Region of the Generation of Oscilltions

To establish the region of generation of oscillation, the intensity of oscillations was measured while varying the distance of the anode from the cathode. The discharge current was kept constant.

It was revealed that oscillations exist at all distances when there is a beam node in the discharge. In these cases the oscillation intensity increased beyond the node towards the anode. If the discharge space is limited by a small anode-cathode distance, the beam does not converge into a node and oscillations do not arise. We can conclude from this that the region of generating strong oscillations is localized in the node zone.

## Conclusions

The conditions for the development of plasma waves for the case of an unbounded plasma are considered in the theory of Bohm and Gross [13] and in a number of other studies [12, 14-16]. Excitation of the wave takes place owing to the interaction of plasma oscillations with the beam electrons, as a result of which the energy of the directed electrons is transmitted to the wave. We can assume that the intensity of the excited wave will increase until dissipation of energy exceeds the energy coming from the beam. Therefore, the intensity of the wave can increase up to a certain value in the direction of the primary beam, and then it should drop. The conditions of the experiments described with large plasma dimensions (large distances of the anode or reflector from the cathode) should be close to the premises of the theory. On the basis of this we can consider that the character of the oscillations investigated in the present experiments under these conditions agree with the anticipated character from the theory of plasma waves in an unbounded plasma.

Regarding the special features of oscillations in a plasma bounded by a comparatively close placement of the electrodes, they can be described on the basis of existing theories [12-16], since these features undoubtedly reflect phenomena taking place at the boundary.

## REFERENCES


1. F. M. Penning, Physica, 6, 241, 1926.
2. A. F. Dittmer, Phys. Rev., 28, 507, 1926.
3. I. Langmuir and Tonks. Phys. Rev., 33, 195, 1929.
4. H. I. Merrill and H. W. Webb, Phys. Rev., 55, 1195, 1939.
5. R. A. Bayley, K. G. Emeleus, Proc. Roy. Irsh. Acad., 57, 53, 1957.
6. D. W. Mahaffey, K. G. Emeleus, Journ. Electr. and Controll., 4, 301, 1958.
7. G. Wehner, Journ. Appl. Phys., 22, 761, 1951.
8. D. K. Looney, S. C. Brown, Phys. Rev., 93, 965, 1954.
9. Kojimaa., K. Kato, S. Hagiwara, Journ. Phus. Soc of Japan., 12, 1276, 1957.
10. M. D. Gabovich and L. L. Pasechnik Zhurn. Eksperim. Teoret. Fiz., 36, 1025, 1959; Radiotekhnika i elektronika, 4, 1851, 1959.
11. R. A. Demirkhanov, A. K. Govorkov, A. F. Popov, G. I. Zverev., Zhurn. Eksperim. Teoret. Fiz., 30, 306, 315, 1960.
12. A. A. Vlasov, Theory of Many Particles, Gostekhizdat, 1950.
13. D. Bohm and E. Gross, Phys. Rev., 75, 1851; 1864, 1949; Phys. Rev., 79, 992, 1950.
14. A. I. Akhiyezer and Ya. B. Faynberg., Zhurn. Eksperim.-Teoret. Fiz., 21, 1262, 1951.
15. M. Sumi, Journ. Phys. Soc. of Japan., 13, 1476, 1958; Journ. Phys. Soc. of Japan, 14, 653, 1959.
16. Yu. L. Klimantovich. Zhurn. Eksperim.-Teoret. Fiz., 36, 1405, 1959.
17. A. A. Zaytsev, G. S. Leonov, I. A. Savchenko. Zhurn. Eksperim. -Teoret. Fiz., 36, 1332, 1959.


Chair of Electronics

Submitted July 8, 1960

DISTRIBUTION LIST

| DEPARTMENT OF DEFENSE | Nr. Copies |
|---|---|
| **HEADQUARTERS USAF** | |
| AFCIN-3D2 | 1 |
| **OTHER AGENCIES** | |
| CIA | 1 |
| NSA | 2 |
| AID | 2 |
| OTS | 2 |
| AEC | 2 |
| PWS | 1 |
| PGE | 1 |
| RAND | 1 |

| MAJOR AIR COMMANDS | Nr. Copies |
|---|---|
| AFSC | |
| SCFTR | 1 |
| ARO | 1 |
| ASTIA | 10 |
| TD-Bla | 3 |
| RADC (RAY) | 1 |
| SSD (SSF) | 1 |
| ASD (DCF) | 1 |
| ESD (ESY) | 1 |
| AFSWC (SWY) | 1 |
| AFMTC (MTW) | 1 |
| APGC (PGF) | 1 |